Claims

1. A method for channel estimation for an optical receiver comprising:

digitizing(13) an analog signal ($\tilde{r}$ (t)) representing a sequence of symbols (d_i) thereby associating one digital word ($r_{i,1}$, $r_{i,2}$) out of a plurality of possible digital words to the level of said analog signal at each sampling time (53, 54); a symbol period (51, 52) comprising at least two sampling times; each digital word corresponding to one out of a plurality of quantization levels (61, 65, 67);

determining (17) the most likely sequence (u_i) of said symbols(d_i);

providing a branch metrics (64, 66, 68, 69, 70, 71, 72, 73);

characterized by

obtaining to said branch metrics (64, 66, 68, 69, 70, 71, 72, 73) from frequencies (63) of digital words ($r_{i,1}$, $r_{i,2}$) resulting from said digitizing (13) and the symbols of said most likely sequence (u_i).

2. A method for channel estimation comprising:

digitizing(13) an analog signal ($\tilde{r}$ (t)) comprising a sequence of symbols (d_i) thereby associating one digital word ($r_{i,1}$, $r_{i,2}$) out of a plurality of digital words to the level of said analog signal at each sampling time (53, 54); a symbol period (51, 52) comprising at least one sampling time; each digital word corresponding to one out of plurality of quantization levels (61, 65, 67);

determining (17) the most likely sequence (u_i) said symbols (d_i);

counting (81) events; thereby obtaining a counter value for each event; each event being defined by a channel state (62) and a current digital word; each channel state being defined by a pattern of symbols relative to a current symbol determined at the time of said current digital word;

characterized by

fitting (82) a model distribution to said counter values; and

obtaining a branch metric (83, 84) on the basis of said fitted model distribution.

3. The method of claim 2, characterized in that a symbol period (51, 52) comprises at least two sampling times (53, 54);

4. The method of one of the claims above characterized by:

counting each kind of events during said digitizing, each event being defined by a channel state (62) and a digital word out of said plurality of digital words; each channel state (62) being defined by a sequence of symbols;

calculating a sample branch metric (64) for each kind of events; and

calculating a branch metric by combining the sample branch metrics (64) for each digital word obtained at a sampling time (53, 54) during a symbol period.

5. The method of one of the claims 1 to 3 characterized by:

each symbol period comprising a first (53) and a second sampling time (54);

associating a first digital word ($r_{l,1}$, 65) at the first sampling time (53) and a second digital word ($r_{l,2}$, 67) at the second sampling time (54) to said analog signal;

counting a first kinds of events, each first kind of events being defined by a first channel state (62) and a first digital word; each first channel state (62) being defined by a sequence of symbols comprising the symbol to which said first digital word is associated;

counting second kinds of events, each second kind of events being defined by said first channel state (62), said first digital word and second digital word following said first digital word;

calculating a first sample branch metric (66) for each first kind of event;

calculating a second sample branch metric (68, 69) for each second kind of event;

calculating a branch metric for a second channel state (62) and a third and fourth digital word by combining the first sample branch metric (66) for said second channel state and third digital word and a second sample branch metric (68, 69) for said second channel state, said third digital word and said fourth digital word; said second channel state (62) being defined by a sequence of symbols comprising a symbol to which said and third and fourth digital words are associated.

6. The method of one of the claims 1 to 3, characterized by:

each symbol period comprising a first (53) and a second sampling time (54),

associating a fist digital word ($r_{l,1}$, 65) at the first sampling time (53) and a second digital ($r_{l,2}$, 67) word at the second sampling time (54) to said analog signal;

counting first kinds of events, each first kind of events being defined by a first channel state (62) and a first digital word; each first channel state (62) being defined by a sequence of symbols comprising the symbol to which said first digital word is associated;

grouping said possible digital words into groups of digital words; associating a coarse digital word to each group of digital words;

counting second kinds of events, each second kind of events being defined by said first channel state (62), the coarse digital word associated to said first digital word and the second digital word following said first digital word;

calculating a first sample branch metric (66) for each first kind of events;

calculating a second sample branch metric (72, 73) for each second kind of events;

calculating a branch metric for a second channel state (62) and a third and fourth digital word, by combining the first sample branch metric (66) for said second channel state and said third digital word and a second sample branch metric (72, 73) for said second channel state (62), a coarse digital word associated with said third digital word and said fourth digital word; said second channel state (62) being defined by a sequence of symbols comprising the symbol to which said third and fourth digital words are associated.

7. The method of claims 1 to 3, characterized by:

each symbol period comprising a plurality of sampling times (53, 54);

counting kinds of events, each kind of event being defined by a first channel state (62), and a digital word ($r_{i,1}$, $r_{i,2}$) for each sampling time during a symbol period of a first symbol;

each channel state (62) being defined by a sequence of symbols comprising the first symbol;

calculating a sample branch metric (70, 71) for each kind of events; and

calculating a branch metric for a second channel state (62) and a second symbol by combining the sample branch metrics (70, 71) for said second channel state (62) and each digital word associated to said second symbol; said second channel state (62) being defined by a sequence of symbols comprising the second symbol.

8. The method of one of claims 4 to 7, characterized in that said sample branch metric is a logarithm of the count of the respective kind of events and combining of sample branch metrics is performed by adding same.

9. The method of one of claims 4 to 8 referring to claim 1, further characterized by:

fitting (82) a model distribution to the counts of each kind of events ;

evaluating (83) the model distribution for each kind of events in order to obtain one model value for each kind of events;

calculating (84) said sample branch metric for each kind of events using the respective model value.

10. The method of one of the claims above, further comprising:

recovering (14) the clock of the symbols; and

delaying (15) said clock in order to minimize the bit error rate of said digitizer by optimizing the sampling times during said digitizing (13).

11. The method as claimed in claim 10, wherein the delay of said clock is adjusted based on bit error rate estimates obtained from said most likely sequence (u_i) of symbols (d_i).

12. The method as claimed in claim 11, wherein the delay of said clock is adjusted in order to maximize a population difference parameter.

13. The method of one of the claims above, further comprising:

adjusting the sampling times by delaying (15) said clock (33) by a delay being quasi-continuously adjustable within a range of half of a symbol period and

performing discrete sampling time (53, 54) adjustment by rearranging (16) the sequence of digital words.

14. The method of one of claims 2 to 13, characterized by:

counting (181) each kind of events during a current accumulation period (k+1), said channel state (62) being determined on branch metrics being calculated (173) during a previous accumulation period (k); and

calculating (183) branch metrics for determining the channel states during a following accumulation period (k+2) while each kind of events is counted (181) during the current accumulation period (k+1).

15. The method of one of claims 1 to 13, characterized by:

calculating (183) the branch metrics for determining the channel states during a following accumulation period (k+2) as the sum of the branch metrics for determining the channel state during the current accumulation period (k+1) weighted by a forgetting factor plus the logarithm of the respective count of events obtained (171) during the previous accumulation period (k) weighted by one minus the forgetting factor.

16. The method of one of claims 1 to 13, characterized by:

calculating (183) the branch metrics for determining the channel states during a following accumulation period (k+2) as the logarithm of the sum of the count of events obtained during accumulation periods before the previous accumulation period (k) weighted by a forgetting factor plus the count of events obtained (171) during the previous accumulation period (k) weighted by one minus the forgetting factor.

17. The method of one of the claims above, characterized by:

defining a channel state (62) as a sequence of binary symbols which may be represented by "0" or "1"; and

setting the branch metrics for the channel states for isolated 0s and 1s i.e."...11011..." and "...00100...", respectively, to identical values when initializing the branch metrics.

18. The method of claim 17, characterized by:

defining a channel state (62) as a sequence of binary symbols which may be represented by "0" or "1"; and

setting the branch metrics of channel states symmetrical to a considered symbol b_3 i.e. $b_1b_2b_3b_4b_5$ and $b_5b_4b_3b_2b_1$ to identical values when initializing the branch metrics.

19. The method of claim 18 characterized by:

monitoring at least one of the following conditions:

a loss of signal output by the physical interface (11) is being cleared (206);

a bit error rate in said most likely sequence (u_i) of symbols is still above a predetermined threshold (207) after a predetermined period of time after the initialization of said branch metrics;

pathological amplitude statistics are determined (208) comprising one of the following cases:

correlation between a only-1 channel state (62) and an only-0 channel state (62) being above a predetermined threshold;

mode of only-1 channel state (62) below predetermined threshold;

mode of only-0 channel state (62) above predetermined threshold; and

correlation of histograms with uniform distribution above a given threshold;

initializing (204) said branch metrics if one of the conditions above occurs.

20. The method of claim 19, characterized in that:

the branch metrics are reinitialized (209, 204) with different values than the values used at the previous initialization.

21. A symbol detector for an optical receiver comprising:

an analog-to-digital converter (13) for digitizing(13) an analog signal ($\tilde{r}(t)$) comprising a sequence of symbols (d_i) thereby associating one digital word ($r_{i,1}$, $r_{i,2}$) out of a plurality of digital words to the level of said analog signal at each sampling time (53, 54); each symbol period (51, 52) comprising at least two sampling times; each digital word corresponding to one out of a plurality of quantization levels (61, 65, 67);

a fractionally spaced maximum-likelihood sequence detector (17) connected to said analog-to-digital converter (13) for determining the most likely sequence (u_i) of said symbols (d_i);

a channel model unit (19) connected to said maximum-likelihood sequence detector (17) in order to provide branch metrics (64, 66, 68, 69, 70, 71, 72, 73) to said maximum-likelihood sequence detector (17);

characterized in that

said branch metrics are obtained from frequencies (63) of digital words ($r_{i,1}$, $r_{i,2}$) output by said analog-to-digital converter (13) and the symbols (u_i) determined by said fractionally spaced maximum-likelihood sequence detector (17).

22. A symbol detector for an optical receiver comprising:

an analog-to-digital converter (13) for digitizing(13) an analog signal ($\tilde{r}$ (t)) comprising a sequence of symbols (d_i) thereby associating one digital word ($r_{i,1}$,$r_{i,2}$) out of a plurality of digital words to the level of said analog signal at each sampling time (53, 54); each symbol

period (51, 52) comprising at least one sampling time (53, 54); each digital word corresponding to one out of a plurality of quantization levels (61, 65, 67);

a maximum-likelihood sequence detector (17) connected to said analog-to-digital converter (13) for determining the most likely sequence (u_i) of said symbols (d_i);

a channel model unit (19) connected to said maximum-likelihood sequence detector (17) for providing branch metrics (64, 66, 68, 69, 70, 71, 72, 73) to said maximum-likelihood sequence detector (17) and for counting events; each event being defined by a channel state (62) and a current digital word; each channel state (62) being defined by a pattern of symbols relative to a current symbol determined at the time of said current digital word; a counter value (63) being associated to each event;

characterized by in that

said channel model unit (19) fits (82) a model distribution to said counter values (63) and obtains (83, 84) a branch metric (64, 66, 68, 69, 70, 71, 72, 73) based on said fitted model distribution.

23. The symbol detector of claims 21 or 22, characterized in that said analog-to-digital converter (13) performs two-fold over-sampling.

24. The symbol detector of one of claims 21 to 23, further comprising a clock recovery subsystem (14) connected to the input of said analog-to-digital converter (13) for receiving said analog signal ($\tilde{r}$ (t)); said clock recovery subsystem (14) for recovering the clock of the symbols;

a sampling phase adjustment circuit (15) connected to said clock recovery subsystem (14) for delaying said clock in order to minimize the bit error rate of said symbol detector by optimizing the sampling times of said analog-to-digital converter (13); said clock recovery subsystem (14) being connected to said analog-to-digital converter (13) for providing said delayed clock to said analog-to-digital converter (13).